PROCESSING VEGETABLE WASTES FOR HIGH-PROTEIN, HIGH-VITAMIN LEAF MEALS

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INTRODUCTION

Certain vegetable wastes are rich sources of protein, carotene, and riboflavin, and studies at the Eastern Regional Research Laboratory have indicated that these valuable nutritional constituents can be made available for use by drying the wastes.[3] Tests have demonstrated the value of these dried wastes as a poultry feed supplement[4] and as a raw material for carotene.[5] Further feeding tests with broccoli have shown that it is superior to standard commercial leaf meals.[6] A survey of the availability of the wastes in terms of quantity, kinds, location, and season has also been made.[7] It is the purpose of this circular to discuss the engineering factors involved in processing the wastes on a commercial scale and to describe a technique for producing a high-quality leaf meal.

The process has been developed only for field and fresh market leafy wastes. Attention has been devoted largely to wastes from beets, broccoli, carrots, kale, lima beans,[8] peas, and spinach. A study on processing cannery wastes will be undertaken later.

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3 Vegetable Wastes as Animal Feedstuffs, by E. G. Kelley, M. E. Wall, and J. J. Willaman. Feedstuffs, vol. 15, no. 26, p. 18, June 26, 1943.

4 Preliminary Investigation on the Use of Certain Dried Vegetable Wastes as Poultry Feeds, by A. E. Tomhave and Edward Hoffman (Delaware Agricultural Experiment Station) in cooperation with E. G. Kelley, Monroe E. Wall, and David A. Colker (Eastern Regional Research Laboratory). Delaware Agricultural Experiment Station Bulletin 247, 32 pp., 1944.

5 Carotene Concentrates from Vegetable Leaf Wastes, by Monroe E. Wall, Edward G. Kelley, and J. J. Willaman. Ind. Eng. Chem. 36, 1057, 1944.

6 Broccoli Leaf Meal for Alfalfa Leaf Meal in Broiler Rations, by Edmund Hoffmann and A. E. Tomhave (Delaware Agricultural Experiment Station) and Edward G. Kelley and Monroe E. Wall (Eastern Regional Research Laboratory). Feedstuffs, vol. 17, no. 8, pp. 25-27, February 24, 1945.

7 Vegetable Wastes. Availability and Utilization, by R. H. Morris, 3rd, D. A. Colker, and M. F. Chernoff, United States Department of Agriculture Mimeograph Circular AIC-51 (Eastern Regional Research Laboratory), August 1944.

8 Bush varieties only were used in these experiments.

The scope of this circular is limited to the method of processing vegetable wastes for leaf meals; the overall economic factors are not discussed. Obviously, to be able to estimate a return on an investment, it is necessary to know the economic value of the product. Additional feed tests are being conducted to determine the potential value of each of the products as compared with that of commercial preparations. A comprehensive publication will shortly be prepared which will discuss additional economic aspects and will also present the latest information on feed value.

THE PROCESS

The method used for drying the leafy wastes is based on the principle of "fractional" drying. By subjecting the fresh material to a high velocity stream of air at a high temperature, the valuable tender leaf portions are quickly dried and embrittled while the more resistant stem portions remain wet and tough. The embrittled leaves are readily separated from the moist stems by simple mechanical methods. The process not only separates the more valuable portions of the waste from the less valuable part but has the additional advantage of requiring less heat for evaporation. This process has been satisfactory for all the wastes studied except pea vines, for which some modification is required.

It is possible to dry the moist stem residue separately for the production of a lower grade product. After the leaf has been separated, the stem can be dried much more readily if it is first chopped into small pieces or crushed. The ultimate result would be two products, one of high nutrient value, the other of low nutrient value. They could be marketed separately or mixed in any proportions to yield products having a nutrient value between the two extremes.

EXPERIMENTAL STUDIES

In evaluating the results of the experimental work to determine the optimum conditions for processing each type of vegetable waste, the following factors were considered:

(1) Yield of product
(2) Composition of product (mainly protein, crude fiber, and carotene content)
(3) Amount of water evaporated per unit weight of product
(4) Economics of the conditions and methods employed

The following variables affect one or more of these factors.

Condition of Raw Material: The physical condition of the raw material as received at the dryer is important. Field wilting, for example, has a deleterious effect on the carotene content of green plant tissues. Serious bruising before field wilting accelerates this action. In the study of vinery wastes from peas and lima beans, the leaf meals obtained by fractional drying and separating were considerably lower in carotene content than were the fresh, hand-separated leaves. Subsequent experimental work by other investigators[9] on lima bean waste, the details of which will be

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[9] E. G. Kelley and M. E. Wall. Unpublished.

published later, have demonstrated that loss of carotene in the bruised leaf just leaving the viner was slight, whereas the bruised leaf analyzed several hours later showed a substantial reduction in carotene.

Since the pilot-plant preparation of leaf meals included an unavoidable delay of several hours between "vining" and drying, one may assume that if the vinery waste were introduced directly into a dryer, the carotene values of the leaf meals would be higher than those obtained in our work.

Chopping before Drying: The effect of chopping prior to drying has been studied with two types of vegetable wastes--carrot tops and broccoli waste. The carrot tops consisted of numerous small leaves and thin stems of low moisture content, whereas the broccoli waste consisted of large, broad, succulent leaves and heavy stems of high moisture content. In each case, the fresh material was chopped in a standard radial-blade forage cutter. No significant difference was observed between carrot tops chopped 1-1/2 inch lengths and those in the whole state. When they were dried and separated under the same conditions, the composition, yield, and amount of water evaporated per pound of product obtained were practically the same. However, since chopped material would be easier to feed to the dryer uniformly and to handle in the dryer and since it would make possible somewhat heavier loadings for the belt-type dryer, chopping fresh carrot tops just prior to drying is recommended.

For broccoli, on the other hand, the results of chopping were quite different. Three sizes of cut were studied, averaging 2-1/2 inches, 1-1/2 inches, and 1/2 inch in length. The finer the chopping the more the dried product lost its original bright-green color. It also appeared, though not conclusively, that the finer chopping resulted in evaporation of more water per pound of product obtained, probably because of the increased exposure of the interior surfaces of the large stems. Finally, the loss in carotene became greater as the chopping became finer, amounting to more than 35 percent for the finest cut. For these reasons, chopping broccoli waste prior to drying is undesirable.

Because of the entangled condition of pea vine waste, chopping is required to permit mechanical loading and handling in the dryer. Although no tests were run on chopped pea vine waste, if done immediately before drying, this step would probably have little effect on the ultimate composition, especially since fine chopping would not be required. Moreover, the yield and the separation after drying would not be affected, since pea vines are dried to completion and screen-separated rather than fractionally dried.

Pressing: A few tests on a hydraulic dewatering press to investigate the possibility of reducing the initial moisture in some of the vegetable wastes prior to drying indicated that this procedure is actually harmful. Because the stem is generally bulkier than the leaf, dewatering takes place mainly in the stem. Pressing also breaks open the stems, causing them to dry more rapidly and making them unsuitable for fractional drying. This, together with the fact that the leaf becomes embedded in the stem as a result of pressing, prevents the subsequent separation of leaf from stem. Moreover, a reduction in valuable constituents might occur as a result of losses in the expressed juices. On the basis of these results, dewatering of field and packing house wastes prior to drying is not recommended.

Drying: In the pilot-plant studies, a tray-type dryer was used that was designed for either through-air circulation or cross-air circulation and equipped for control of wet- and dry-bulb temperature, air velocity, and percentage of air recirculated. The experiments were designed, however, to parallel the action of a continuous, conveyor-type dryer.

The effect of drying temperature was studied on hand-stripped leaves, mainly from beets and broccoli. Hand-stripped leaves were chosen to eliminate the effect of drying temperature on the efficiency of separation of stem from leaf. The temperature ranged from 125° to 300° F., and the leaves were dried to approximately 5% moisture. The dried product was analyzed, and the results were compared with the results of analysis of undried hand-stripped leaves. No significant differences in analyses were noted, although a scorched odor was detected in the product dried at 280° and above. Scorching reduces the value of the product for feed purposes.

An inlet dry-bulb temperature of approximately 240° F. was eventually decided upon as most satisfactory in our equipment for paralleling the temperature in a continuous-type conveyor dryer. Temperatures below this figure resulted in drying rates too slow for economical operation. Furthermore, slower drying caused more evaporation from the stem portions, resulting in greater fuel consumption and less efficient separation.

Temperatures between 240° F. and the scorching temperature might be employed in a continuous dryer with increased drying rates over that indicated at 240°, and temperatures above this scorching temperature might also be used in the early stages of drying. However, certain difficulties are encountered when the drying rate is increased. For example, with wastes of the broad leaf type, fractional drying can be practiced only if fresh areas are periodically exposed to the drying medium during the operation. This is accomplished by mechanically tossing or turning the material at the proper periods during the drying cycle. To avoid unnecessary drying of the stems and over-drying of the leaf, this tossing should be done as soon as the leaves on the top layer become embrittled. This becomes increasingly difficult as the drying rate increases.

The humidity in the dryer was made to parallel the conditions in a continuous, reheat-type dryer operating at 240° F. This was achieved by venting approximately 15 percent of the air from the dryer.

Air flow in most of the experimental work was maintained at an approximate value of 175 cubic feet of air per square foot of tray area per minute; the air was directed down through the material, since this is typical of rapid, through-circulation, conveyor-type dryers. The velocity through the material is actually much higher than this figure, since the free area through the material is considerably less than the area of the tray. A few tests with volumes at 100 cubic feet per square foot per minute showed considerable decrease of drying rate, together with the attendant disadvantages for fractional drying. At the higher velocity, loss of static pressure through the bed ranged from 0.3 to 0.6 inch of water, which is well within the limits of commercial practice.

To simplify the operation of a commercial dryer, studies were undertaken to arrive at a standard drying schedule for all the wastes, the only variation being in the rate of feed of fresh material (initial loading per square foot) to account for the differences in initial moisture content and the physical nature of the material. The recommended initial loadings for each waste and the drying schedule are given under "Operating Procedure."

EQUIPMENT REQUIRED

A suggested assembly of the equipment is shown in the flow diagram on page 17.

Cutting: As indicated above, chopping is required for processing pea vines, and it is desirable for carrot tops. A cutting machine is also required if the wet residues from the dryer are reprocessed after the leaf has been separated. A rotary forage cutter with readily removable screen and adjustable length of cut would be the best type for these purposes. A screen having holes approximately 2 inches in diameter should be provided. It would be removed from the cutter when the fresh vegetable waste is chopped but would be installed when the residue is chopped for redrying. The machine should be designed to produce a clean cut with a minimum of bruising when used without the screen. A machine having an hourly capacity of 3 to 4 tons of fresh waste per hour would require 15 horsepower and should cost approximately $800, including the cost of the motor.

Drying: The experimental studies showed that a multiple-belt conveyor dryer would be best adapted for maintaining a temperature of 230° to 250° F. for the air supplied to each belt, a volume of approximately 175 cubic feet of air per square foot per minute, and a periodic turning or rearrangement of the material. This dryer has the advantage of being continuous as well as of allowing the turning action to take place within the heated zone. Furthermore, the control of air temperature throughout the cycle and the uniformity of distribution of the air can be accomplished with comparative ease in a dryer of this type.

Since the leafy structure of the vegetable waste becomes limp as soon as it is heated, it seals off the air passages and reduces air circulation through the material. Thus, the maximum fresh loading permissible per square foot of belt area is relatively light. Should this light loading be maintained throughout, the dryer would have to be abnormally long for a given capacity. However, as drying progresses, the plant shrinks and stiffens, permitting heavier loading while still maintaining sufficient porosity for air circulation. This fact can be utilized to advantage by operating each succeeding belt at a lower speed. In this way, the quantity of material per square foot of belt area is progressively increased, thereby increasing the overall capacity of the dryer. The transfer from one belt to the next also achieves the required turning action. This procedure has the further advantage of balancing the evaporation load for each belt. This is accomplished because the drying rate is greatest in the early stages of drying and decreases as drying progresses. Therefore, in the later stage in drying, more material should be handled per square foot to make evaporation equivalent to that in the early stages. Finally, the procedure of successive increases in belt loading also equalizes the loss of static pressure in the air passing through the belt during drying.

The greater the number of belts, the greater is the number of turnings and, theoretically, the greater is the overall rate of drying. Practical considerations, however, limit the number of belts used in standard dryers. In our pilot-plant drying work, it was found that two turnings, with successive doublings in loading, were adequate for successful results. This would warrant the use of a 3-belt conveyor, each belt having the same drying length. Two arrangements are possible for a multiple-belt dryer, the multiple-deck type and the extended type. Each has advantages and disadvantages, depending not only on the particular features of the dryer but also on local conditions.

In general, the dryer should consist essentially of conveyor belts constructed of sturdy, flexible, wire mesh (3/16-inch maximum holes), preferably galvanized, with a retaining apron at least 8 inches high on each side of the last belt. The speed of the belts should preferably be capable of variation. This will greatly increase the utility of the dryer at only a slight increase in cost. A feeding unit of variable speed, with a loading hopper, should also be provided. Suitable kicking devices synchronized with the movement of the belt should be included at the discharge end of each belt to open the mat of material as it falls from one belt to the next.

Sufficient fan capacity and ductwork should be provided to maintain the required air flow, to distribute the air uniformly over the conveyor area, and to exhaust an adequate amount of waste air at suitable locations.

The dryer can be heated most economically by a mixture of dilution air and flue gases. The furnace should be designed to operate at temperatures adequate to give clean flue gases. Suitable automatic controls for maintaining the required temperature in the dryer should be furnished, and in addition, a safety device should be provided to vent the flue gases from the burners in the event of an emergency causing over-heating in the dryer.

The entire dryer should be adequately supported and enclosed with materials having good insulating value. By using the information given here, the detailed design of the dryer can be worked out with any reputable manufacturer of drying machinery.

The actual size of dryer required would naturally depend on the quantities of waste available and hourly capacities desired, but for the purposes of general discussion and comparison of capacities for different wastes, a dryer having a total drying area of 930 square feet has been selected. With a belt 8-1/2 feet wide, a 3-belt, multiple-deck dryer with this drying area would be approximately 40 feet long and require a total of approximately 65 horsepower for fans and conveyors. A unit of this size having the general characteristics outlined above would cost about $40,000. This would include the cost of installing it in a corrugated metal building and the cost of the building.

Mechanical Separation: A rotating screen, or trommel, is required for separating the dried leaves from the wet stems. To handle the output of the dryer described, this trommel should be approximately 4 feet in diameter and 14 feet long and should be covered with heavy wire mesh having 3/16-inch openings. Six lifting baffles about 2 inches high should be placed at equal distances around the circumference running the full length of the unit, and short sections of chain weighing approximately one-half pound per foot should be attached at about every 10 inches on each baffle. The chains should be just long enough to strike the full width of the circumference between baffles. The trommel should be designed to operate at 24 revolutions per minute and should be provided with convenient means for adjusting the pitch to accommodate different rates of discharge from the dryer. This unit would require 5 horsepower for operation and would cost approximately $700, including the cost of the motor.

Screening: A two-stage vibrating screen of a conventional type is required for the removal of soil and small stems that pass through the trommel screen. Each stage should have a screening area of at least 30 square feet. At least 3 sieves are required, 3 mesh (about 0.28-inch opening), 20 mesh, (0.034-inch opening), and 60 mesh (0.009-inch opening). For simultaneous removal of stems and soil, the screen is used as a two-stage unit, the 3-mesh sieve being placed above the 60-mesh sieve. As explained later, the 20-mesh sieve is used alone for processing pea vines. The sieves should be the self-cleaning type, and they should be readily interchangeable. Such a screen requires approximately 2 horsepower for operation and costs about $1300, including the cost of the motor.

Milling: A hammer mill of the type generally used for producing poultry feed meals should be provided. In addition to the standard screen for producing 1/20-inch meal, a screen with a 1/4-inch opening should be provided for processing pea vines. The mill should be equipped with a magnetic separator on the feed end, a discharge fan, and a cyclone separator with a 2-way sacker. This unit requires 30 horsepower and costs approximately $1500, including the costs of the interconnecting ductwork and the motor.

Miscellaneous: In addition to the items specified, the plant requires the ductwork and damper valves to connect the various pieces of equipment and to direct the flow of material. An inclined cleated belt conveyor is required to carry the material from the dryer to the next operation. Since the material discharged from the dryer is bulky, this conveyor should have large volumetric capacity. Additional items required are the conduit and wiring for all the motors. These items should bring the total cost of the entire installation, including the building, to about $48,000.

OPERATING PROCEDURE

On the basis of the pilot-plant work, the following operating procedures are recommended:

The fresh vegetable waste should be dumped into a hopper at ground level from which a mechanical feeding device would load the dryer belt uniformly at a predetermined loading rate. In drying pea vines or carrot tops, the waste should be cut in a forage cutter set for coarse chopping before it is charged into the feed hopper of the dryer. Pea vines should be cut into 3- to 6-inch pieces and carrot tops into 1-1/2- to 3-inch pieces.

The dryer should be operated according to the following drying schedule. This schedule may be subject to some slight modification when used on a commercial scale, since the procedure recommended is based on tests in a batch tray dryer. On the whole, however, the results should be readily reproducible commercially, since conditions maintained in the tray dryer can be duplicated in a conveyor-type dryer. Moreover, somewhat better results might be obtained in commercial practice, in view of the fact that in a continuous dryer the turning action can take place instantaneously within the dryer, whereas in the pilot-plant work, the trays were removed from the dryer and the material was turned by hand. The latter procedure resulted in cooling the material considerably. Also, in the continuous process the fractionally dried material would discharge directly and continuously into a rotating trommel, whereas in the pilot plant the material from all the trays was collected and charged as a batch into the trommel. The delay in the latter method resulted in some rehydration of the dried leaves, thereby reducing the yield.

The loading per square foot of belt area, together with the average moisture content of the various green wastes, is shown in Table I.

The schedule for operating the dryer consists simply in running the first belt at such a speed that the vegetable material is carried for a period of 5 minutes. The second belt is operated at half the speed of the first; thus the material remains on the second belt for 10 minutes at double the original loading. The third belt is operated at half the speed of the second; thus, the material remains on the third belt for twenty minutes at four times the original loading. On this basis, with a total drying time of 35 minutes, the average dry weight loading per square foot for the entire dryer is one-third the sum of the individual loadings on each belt. To operate on this schedule, the temperature of the air entering to each belt should be maintained at approximately 240° F., and the volume of air should be approximately 175 cubic feet for each square foot of belt area.

From the dryer, the product discharges directly into the continuous trommel, through which it passes in 2 to 4 minutes. The wet residue in the trommel discharges at the end and is carried for subsequent chopping and redrying or for disposal. The fines passing through the trommel screen can be directed to any of the following operations (see flow diagram), depending on the use intended:

1. Bagging. (When finely ground material is not required.)
2. Hammer milling, then bagging. (For use as poultry feed fortifiers.)
3. Screening for removal of small stems and fine soil which come through the trommel. (This is desirable when a highly concentrated leaf meal is required or when the vegetable waste is dirty. Screening can be followed by step 1 or step 2.)

In processing pea vines, the operations following the dryer are somewhat different. The dry product bypasses the trommel and goes directly to a hammer mill provided with a screen having 1/4-inch openings. The hammer-milled product is carried through the cyclone collector and discharged on a vibrating screen equipped with a 20-mesh sieve, which separates the residue from the leaf in about a 50-50 ratio. The leaf can be bagged directly from the screen. The residue is also dry at this point and can be bagged for use as chicken litter or for other purposes.

YIELDS AND ANALYSES

As a result of numerous pilot-plant runs, the average yield of leaf meal was determined. This figure will obviously vary with the moisture content of the waste. Table II gives the average yield and composition of the product from each vegetable waste studied. The amount of stems and soil screened off is also shown as well as the amount of residue discharged from the trommel and its average moisture content.

Table III indicates the hourly performance of the dryer for each of the vegetable wastes. Since the output of the dryer is proportional to the amount of evaporation required, the performance of the dryer varies as the moisture content of the waste varies.

COST OF PROCESSING

Since the cost of the commercial processing of vegetable wastes will depend on many factors, and will vary from one plant to the next, it is impossible to estimate the exact overall cost. However, the principal costs involved and a method of computing them are explained, and on the basis of stated assumptions, the average cost of processing each waste is given (Table IV). These figures do not include charges for raw material, haulage, storage of product, or rent.

Operating Costs: Operating costs consist mainly of the costs of fuel, power, labor, supplies, and maintenance, and clerical work. The type of fuel will depend on the design of the dryer and the relative cost of the various fuels delivered to the plant. For purposes of computation, the use of fuel oil with a thermal value of 145,000 Btu per gallon is assumed. Fuel consumption is based on a dryer efficiency of 2000 Btu per pound of water evaporated. For power, an average cost per kilowatt hour is assumed. The labor for operating the dryer and bagging the product should consist of one operating supervisor and two laborers. Hourly rates for labor and clerical work, and an hourly cost for miscellaneous supplies and maintenance are also assumed. Since the cost of bags for shipping the dried product is charged to the consumer, this cost is not included. The assumed costs are: Fuel, $.04 per gallon; power, $.025 per kilowatt hour; skilled labor, $1.00 per man hour; unskilled labor, $.625 per man hour; clerical, $.50 per operating hour; maintenance and supplies, $.35 per operating hour.

With these assumed costs, the operating costs per hour can be figured for each waste individually. The yearly operating costs, however, will naturally depend on the proportions of the different wastes processed.

Fixed Costs: The yearly fixed costs are based on the total investment. The assumed values are listed below.

Item	Percent of Investment per year
Amortization	10
Interest	6
Insurance	1-1/2
Taxes	2
Total	19-1/2

To reduce this figure to an hourly rate, the total hours of operation must be known. Obviously, the greater the number of hours, the lower will be the fixed costs per hour. Under certain conditions, for example, when a lull is expected in packing house operations, it may prove economical for the processor himself to grow some of the more nutritionally rich products just for drying. Experiments on growing closely planted broccoli for this purpose have been carried out. The results will be published later.

For the purpose of calculating fixed costs, a total of 2000 operating hours per season is assumed.

The operating cost per hour and the total cost per pound of product for each vegetable waste are given in Table IV. The following is a sample calculation of the total cost of processing broccoli waste.

CALCULATION OF COST OF PROCESSING BROCCOLI WASTE

	Dollars per hour	
<u>Operating Costs</u>		
<u>Fuel</u>		
$\frac{4300 \text{(lbs. water evap/hr)} \times 2000 \text{(Btu/lb. water evap)}}{145{,}000 \text{(Btu/gal.)}} \times \$.04$	2.37	
<u>Power</u>		
(including power for screening and hammer milling)		
$\frac{105 \text{(required hp.)} \times 0.746 \text{(kw./hp.)}}{0.8 \text{(power factor)} \times 0.85 \text{(motor efficiency)}} \times \$.025$	2.88	
<u>Labor</u>		
1 supervisor at $1.00 2 laborers at $0.625 each 1 clerk at $0.50	2.75	
<u>Maintenance and Supplies</u>	0.35	
Total		8.35
<u>Fixed Costs</u>		
$\frac{\$48{,}000 \text{(total investment)}}{2000 \text{(operating hours)}} \times .195$ (% of investment per year)	4.68	
Total		4.68
Total hourly costs		13.03
Total cost per pound of leaf meal $(\frac{13.03}{500})$		$0.0261

In processing broccoli waste, both the residue from the trommel and the screened stems have considerable value (Table II). The wet residue can be redried in the same dryer if it is chopped prior to drying. Table III shows that operating the dryer for one hour produces 500 pounds of leaf meal, 40 pounds of screened stems, and 730 pounds of residue at 68.4% moisture. Drying this residue to 10% moisture would yield 256 pounds of dried residue and would require the evaporation of 474 pounds of water. Since the dryer has an average evaporating capacity of 4500 pounds of water per hour, it should be capable of producing 2430 pounds of dried residue per hour. This would be the equivalent of drying in one hour the residue produced from operating the dryer for 9.5 hours for production of leaf meal. The total cost per pound of drying the trommel residue, figured in the same manner as the foregoing, is \$.0055.

Thus, the cost of drying the <u>entire</u> broccoli waste may be calculated as follows:

Leaf meal	500 pounds	x	\$.0261	=	\$13.03
Residue	256 pounds	x	\$.0055	=	1.41
Screened stems	40 pounds	x	\$.00	=	.00
Total	796 pounds			=	\$14.44

$$\frac{14.44}{796} = \$.0182 \text{ per pound}$$

OTHER METHODS OF PROCESSING

The major difference in other methods of processing would be in the type of drying equipment employed. Although dryers of other types were not included in these experiments, some generalizations can be made as to their possible utilization on the basis of the conditions required in the dryer and the relative economy of the different types. Three general types of drying equipment will be discussed here--the tray-truck, the loft, and the rotary. Obviously vacuum dryers for this purpose would be out of the question.

The tray-truck dryer is used either as a batch unit in a cabinet or a continuous unit in a tunnel. In either case, the truck is equipped with numerous trays, thus making possible heavy loading per cubic foot of dryer. On the other hand, there are two distinct disadvantages in using this drying method for processing vegetable wastes. The first is a result of the fact that large quantities of bulky material are required to produce an appreciable quantity of product. Since loading trays is costly, the use of tray drying may prove uneconomical. A second disadvantage is based upon the fact that in fractional drying of many materials, a periodic turning over or redistribution of the bed is necessary. This is practically impossible in a tray dryer. The only alternative to this turning process is to use extremely light loadings per tray, but this would magnify the first disadvantage mentioned. Thus, tray-truck drying is not economically feasible for processing vegetable wastes.

The loft dryer ordinarily consists of a perforated metal or slotted wooden floor erected over a direct source of heat. In the majority of these installations, the draft is maintained through natural convection. Although the large holding capacity permits a low-cost loading operation, such a unit is unsuited for the required rapid fractional drying. The drying rate is low, mainly because of limited air velocity. Furthermore, if some fractional drying were effected, the fragile dried portion would be seriously rehydrated during unloading, and part of it would be lost through the loft floor. Thus it would appear that fractional drying would not be practicable in a loft dryer. When the entire waste material is to be dried, however, this type of dryer may be used.

There are many variations of the rotary dryer. In the type used for most forage drying, hot air dries the finely chopped material and conveys it through the dryer in a short time. The capital cost of such a dryer is generally less per unit of evaporative capacity than the type recommended in this circular. It can be seen at once that the possibilities of using this type of rotary dryer differ for different wastes. For such materials as chopped pea vines, chopped carrot tops and possibly lima bean waste, it might prove satisfactory. Since the entire product would be dried, the subsequent separation would be taken care of much in the same manner as that described for pea vines under "Operating Procedure." With the exception of chopped pea vines, the products obtained by this method of drying and separating would probably not be so pure as those obtained by fractional drying and trommeling.

Considerably more difficulty would be encountered in using this type of dryer for drying the more succulent, broad-leaf wastes such as broccoli beet, kale, and spinach. Fine chopping, which is a necessary preliminary in the use of the air-conveying type of rotary dryer, causes considerable juicing and pulping, resulting in difficulty in feeding the dryer. Furthermore, as shown under "Experimental Studies," chopping broccoli waste results in a product having a lower carotene value. This can be expected to prove true for other materials of the same type. Thus, although some kinds of rotary dryers might be used for some wastes, in general the high-temperature, air-conveying dryers are not recommended for processing some wastes, including the leafy type.

TABLE I

DRYER BELT LOADINGS FOR VARIOUS VEGETABLE WASTES

Vegetable waste	Average initial moisture	Fresh weight per square foot of first belt	Dry weight per square foot of first belt	Dry weight per square foot of second belt	Dry weight per square foot of third belt	Average dry weight of loading per square foot of drying surfaces
	percent	pounds	pounds	pounds	pounds	pounds
Broccoli[a]	86.9	1.5	0.20	0.40	0.80	0.47
Beet tops	88.6	1.5	0.17	0.34	0.68	0.40
Spinach[b]	87.0	1.5	0.20	0.40	0.80	0.47
Kale[c]	81.4	2.0	0.37	0.74	1.48	0.86
Carrot tops (early)	68.5	2.0	0.62	1.24	2.48	1.45
Carrot tops (late)	79.7	1.8	0.37	0.74	1.48	0.86
Lima[d]	71.2	1.8	0.52	1.04	2.08	1.21
Pea vines	81.5	1.5	0.28	0.56	1.12	0.65

(a) Waste from the sorting belt in preparing heads for market or freezing.

(b) Wintered-over material that had gone to seed and was to be plowed under.

(c) Since waste was not available, fresh market material was used for these experiments.

(d) The apron fraction, which is the side fraction from the viner and consists mainly of broken leaf, was caught before it could mix with the end fraction, which was mainly stem.

TABLE II

AVERAGE YIELD AND COMPOSITION OF LEAF MEAL FROM VARIOUS VEGETABLE WASTES[a]

	Broccoli	Beet tops	Spinach	Kale	Carrot tops Early	Carrot tops Late	Lima	Pea vines
Fresh material								
Moisture, %	86.9	88.6	87.0	81.4	68.5	79.7	71.2	81.5
Leaf meal								
Yield, basis fresh material, %	8.9	7.9	8.9	11.1	18.8	12.8	24.5	9.7
Moisture, %	7.6	4.5	5.6	2.3	4.8	7.0	4.6	6.8
Leaf meal analysis, bone-dry basis								
Protein, %	35.3	24.8	31.6	27.2	10.4	13.0	13.7	14.6
Crude fiber, %	8.4	6.9	9.7	6.6	13.7	10.2	9.2	18.8
Ether extract, %	7.6	7.1	6.8	7.1	6.6	2.6	4.0	4.1
Carotene, ppm (b)	595	413	466	338	111	184	197	85.2
Riboflavin, ppm	25.1	23.9	29.1	15.3	6.4	8.0	9.6	16.8
Trommel residue								
Yield, basis fresh material, %	13.1[c]	6.1	12.1	26.0	16.0	19.2	4.0	10.7
Moisture, %	68.4	49.2	62.0	68.8	44.0	67.0	20.0	12.3
Screened stems and soil								
Yield, basis fresh material, %	0.8[d]	0.8	-	-	4.2	2.0	2.3	-

(a) For raw material described in Table I.
(b) Ppm of carotene x 754 = International Units per pound.
(c) Broccoli trommel residue when chopped and dried had 21.3% protein, 16.9% crude fiber, 3.5% ether extract, 43.0 ppm carotene, and 7.1 ppm riboflavin.
(d) Screened broccoli stems had 22.4% protein, 20.6% crude fiber, 2.4% ether extract, 81.4 ppm carotene, and 7.8 ppm riboflavin.

TABLE III

PERFORMANCE OF 3-BELT DRYER WITH 930 SQUARE FEET OF DRYING AREA [(a)]

					Carrot tops			
	Broccoli Lbs./hr.	Beet Tops Lbs./hr.	Spinach Lbs./hr.	Kale Lbs./hr.	Early Lbs./hr.	Late Lbs./hr.	Lima Lbs./hr.	Pea Vines Lbs./hr.
Fresh waste	5580	5580	5580	7450	7450	6700	6700	5580
Leaf meal (as is basis)	500	440	500	830	1400	860	1640	540
Wet residue	730	340	675	1920	1200	1290	265	595
Stems and soil screened off	45[(b)]	45	-	-	315	130	155	-
Water evaporated	4300	4750	4400	4700	4530	4420	4640	4470

(a) For raw material described in Table I.

(b) Consisted of 40 pounds of stems and 5 pounds of separated soil

TABLE IV

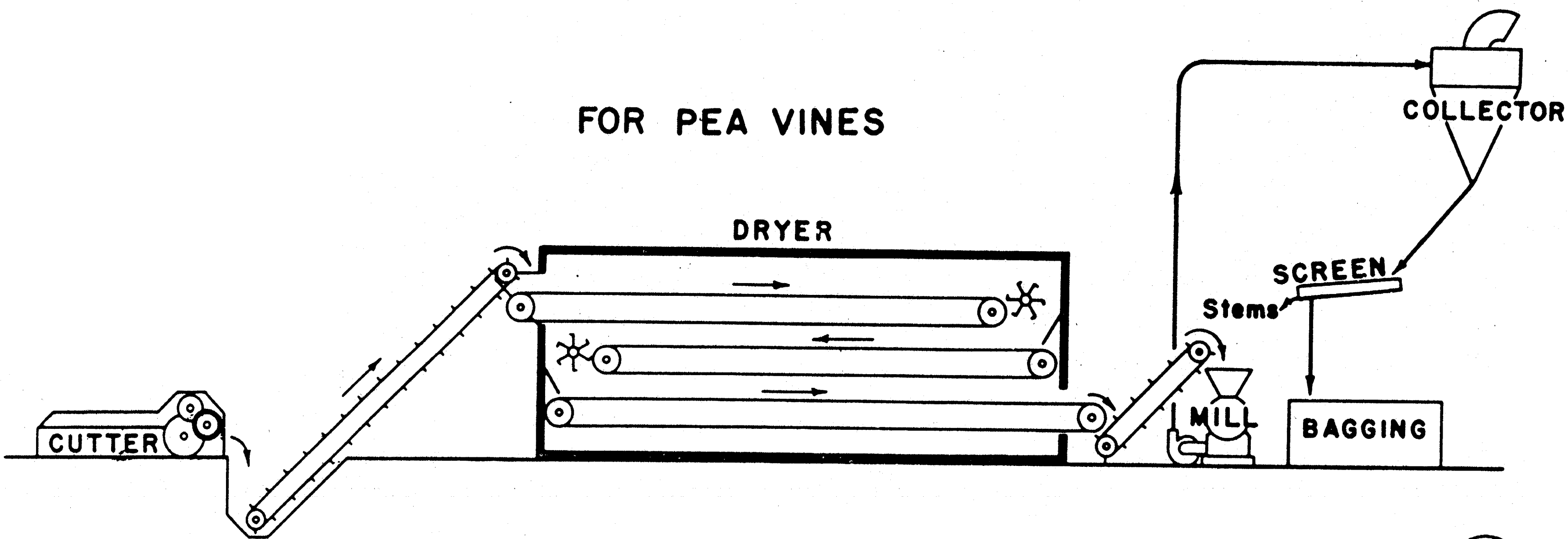
COST OF PROCESSING VARIOUS VEGETABLE WASTES[a]

Vegetable waste	Operating cost per hour	Total cost per pound
Broccoli (leaf meal)	$8.35	$0.0261
Broccoli (entire waste dried)	8.68	.0182
Beet tops	8.60	.0302
Spinach	8.41	.0261
Kale	8.57	.0160
Carrot tops (early)	8.89	.0097
Carrot tops (late)	8.83	.0157
Lima	8.54	.0081
Pea vines	8.72	.0248
Pea vines (based on utilization of all the dried product)	8.72	.0118

(a) Raw material described in Table I.

FLOW DIAGRAM

FOR PEA VINES



FOR OTHER VEGETABLE WASTES